

## DESCRIPTION

METHOD OF MANUFACTURING HIGH PURITY EPOXY RESIN AND  
EPOXY RESIN COMPOSITION

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## Field of the Invention

The present invention relates to a method of manufacturing a high purity epoxy compound and to an epoxy resin composition using the high purity epoxy compound and used for reliably sealing electronic components.

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## Background of the Invention

Because of their excellent characteristics, epoxy resins have been widely used in various fields, such as electrical and electronic devices, paints, in the fields of architecture and civil engineering, and adhesives. Especially in the field of electrical and electronic devices, epoxy resins have been widely used as sealing material for electronic components because of their excellent characteristics in electrical insulation and thermal resistance. In recent years, due to tendency for more and more highly integrated semiconductor device, for further reduction of size and thickness of packages, and for higher packaging efficiency, improvement of reliability is strongly required for epoxy resins used in these applications.

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Two main approaches have been adopted for improving reliability of epoxy resins. In the first approach, decrease of the content of halogen-containing group which is present in trace amount in epoxy resins has been attempted. It has been known that hydrolysis of a halogen-containing group in epoxy resins results in degradation of electrical insulation and corrosion of lead wires, and thus adversely affects reliability of electronic devices.

In the second approach, reduction of stress and

reduction of moisture absorption of hardened epoxy resins have been attempted. Conventionally, an epoxy resin composition that is composed of a cresol novolac type epoxy resin as a epoxy resin, a phenolic resin as a curing agent, and silica or the like as a filler, has been widely used for sealing semiconductor devices. However, although the cresol novolac epoxy resin has excellent thermal resistance, it has a disadvantage that hardened product lacks flexibility so that cracks tend to be produced in the moldings.

In order to obtain an epoxy resin composition with low hygroscopicity, it is desirable to use the so-called filler high-filled type epoxy resin composition that contains a large amount of filler with low hygroscopicity such as silica. However, use of a cresol-novolac resin leads to increase in the viscosity of the epoxy resin composition at the time of molding, and may result in problems such as molding failure or damage to the sealed micro-electronic parts.

Various processes have been proposed to resolve these problems. In the above-mentioned first approach to improving reliability of an epoxy resin composition, that is, in order to reduce a halogen containing group that is present in trace amount in an epoxy resin, a process is disclosed in Japanese Patent Publication No. 61-136513, in which an alkali metal hydroxide is added to react with an epoxy resin in the presence of isobutanol or a solvent consisting of a secondary alcohol. A process is also disclosed in Japanese Patent Publication No. 62-64817, in which an epoxy resin is reacted in the presence of alcohols, alkali metal hydroxide, and a phase transfer catalyst at temperature of 20 ~ 50°C.

Since, in the process as disclosed in the above-mentioned Japanese Patent Publication No. 61-136513, isobutanol or a secondary alcohol is used, reaction of these alcohols with the epoxy group is induced during the reaction and the epoxy equivalent is thereby undesirably

increased. Also in the process as disclosed in the above-mentioned Japanese Patent Publication No. 62-64817, although the reaction takes place at relatively low temperature, a phase transfer catalyst is used and  
5 reaction of alcohols and the epoxy group is likely to be induced. Use of expensive catalyst is a disadvantage as industrial application.

A process is disclosed in Japanese Patent Publication No. 62-256821, in which halogen content in  
10 epoxy resin is decreased by processing a raw epoxy resin which is prepared by reaction of bisphenols obtained by substituting ortho-position of phenolic hydroxide, and epihalohydrin, in an alkaline solution with water content at a predetermined level or lower. Also in Japanese  
15 Patent Publication No. 63-268723, a process is disclosed for decreasing hydrolyzable halogen content of epoxy resin by adding aqueous solution of alkali metal hydroxide and hydrophobic solvent to a raw epoxy resin prepared from poly-phenol and epihalohydrin, and by  
20 extracting water from the system by azeotrope of the hydrophobic solvent and water to thereby give rise to ring reclosure reaction.

In the process disclosed in the above-mentioned Japanese Patent Publication No. 62-256821, as described  
25 in the specification of the Patent Publication, total chlorine content of 600 ppm or lower is difficult to be achieved except for the epoxy resin having the specific structure which is obtained by reaction of bisphenol having substituted ortho-position of phenolic hydroxide, and epihalohydrin. Even when total chlorine content of  
30 600 ppm or lower is achieved, undesirable reactions such as ring opening of the epoxy group may occur, as described in the Patent Publication, so that this method cannot be used for general industrial applications.

35 In the process disclosed in the above-mentioned Japanese Patent Publication No. 63-268723, due to high water content of the system in the initial stage of the

reaction, the epoxy group may react with water in the system using the alkali metal hydroxide as a catalyst, resulting in ring opening of the epoxy group. As a result,  $\alpha$ -glycol may be produced, leading to lowering of the epoxy group content. Produced  $\alpha$ -glycol has a hydroxide group of primary alcohol with relatively high reactivity. Thus, when an epoxy resin with sufficiently low chlorine content is to be obtained, the hydroxide group of the produced  $\alpha$ -glycol may react with the epoxy group, which may results in undesirable polymerization or gel formation.

In the second approach to improving reliability of an epoxy resin composition, that is, in the attempt to decrease stress and moisture absorption of the hardened epoxy resin, a low molecular weight bi-functional epoxy resin composition having two epoxy groups per molecule has been conventionally used effectively. Since cross-link density is low for bi-functional epoxy resin, the hardened product is of low stress, and by using a low molecular weight epoxy resin, it is possible to overcome the problem of molding failure and damage to the sealed minute electronic components even when a large amount of filler is filled in the epoxy resin composition. However, since an epoxy resin composition using such a bi-functional epoxy resin has lower cross-link density as compared to an epoxy resin composition using a multi-functional epoxy resin, it has a disadvantage that the thermal resistance is also degraded.

In order to resolve this problem, a process for production has been known in which alcoholic hydroxide group that is present in the bi-functional epoxy resin is reacted with epichlorohydrin to obtain glycidyl ether, and thus to provide branching structure of glycidyl ether in the molecule. Also a process is disclosed in Japanese Patent Publication No. 04-353517, in which alcoholic hydroxide group in an epoxy resin having three or more

phenolic glycidyl ethers in a molecule, is reacted with epichlorohydrin to obtain glycidyl ether and thereby to improve thermal resistance and water resistance.

5 However, although these processes are effective in improving thermal resistance and water resistance, multi-functionalization by introducing an epoxy resin of short chain length such as epichlorohydrin may result in increase of the elastic modulus, and therefore is undesirable from the viewpoint of decreasing stress.

10 Especially in recent years, due to remarkable progress toward more and more highly integrated semiconductor device, toward reduced size and thickness of packages, and higher packaging efficiency, improvement of reliability is strongly required for epoxy resins used  
15 in these applications, and therefore, there is still a strong need for decrease of the content of halogen containing group that is present in trace amount in epoxy resins as well as for reduction of stress and moisture absorption of hardened epoxy resins.

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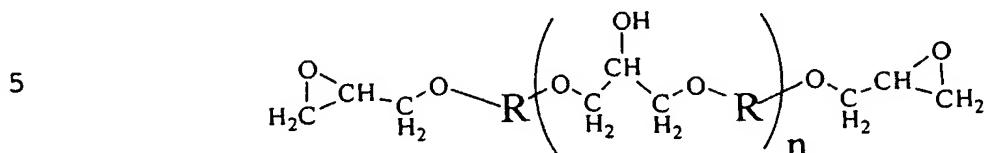
#### Disclosure of the Invention

It is therefore an object of the present invention to provide an epoxy resin that permits the content of halogen containing group that is present in trace amount  
25 in epoxy resin to be decreased, and at the same time permits stress and moisture absorption of the hardened epoxy resin to be reduced.

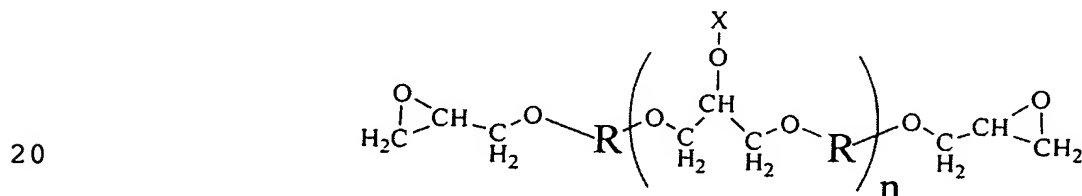
The present inventors have found, after intensive study conducted to resolve above problems, a novel fact  
30 that, when total chlorine content of an epoxy resin is at a specified level or lower and when the epoxy resin has a specified branching structure, above-mentioned problems can be overcome, and thus have arrived at the present invention.

35 Thus, in accordance with the present invention, there is provided a process for production of a high-purity epoxy compound with total chlorine content of less

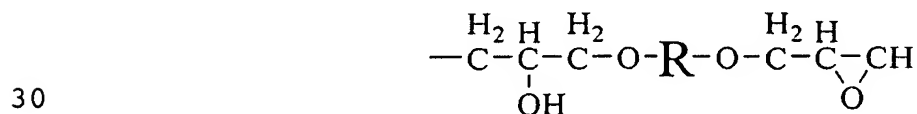
than 500 ppm, characterized in that an epoxy compound represented by the following general formula (I):



(wherein, R represents a dihydric phenol compound residue and/or a dihydric alcohol compound residue; and n represents a numerical value with the average greater than 0 and not greater than 10), in which the proportion of the component having n equal to 0 is more than 70% and less than 100%, is reacted in the presence of alkali metal hydroxide at temperature of 95°C ~ 150°C to produce an epoxy compound represented by the following general formula (II):



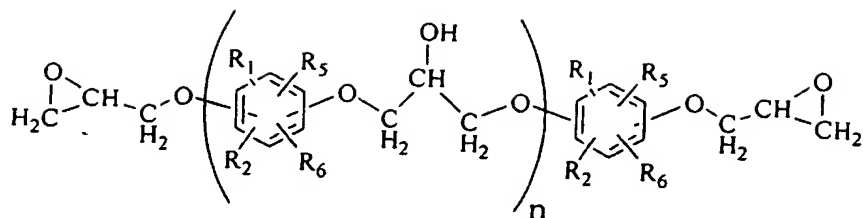
[wherein, R represents a dihydric phenol compound residue and/or a dihydric alcohol compound residue; n represents a numerical value with the average greater than 0 and not greater than 10; and X is a hydrogen atom or a group represented by the following general formula (III):



(wherein, R has the above-mentioned meaning)], in which component with X represented by the general formula (III) is always contained.

In the above-described process, in accordance with a preferred aspect, the manufactured epoxy compound consists of an epoxy compound represented by the general formula (I) in the ratio of not less than 90% and less





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[wherein,  $R_1$ ,  $R_2$ ,  $R_5$ , and  $R_6$  represent hydrogen, alkyl, allyl, phenyl group, or halogen atom, and may be same or different; and  $n$  is a numerical value with average greater than 0 and not greater than 10].

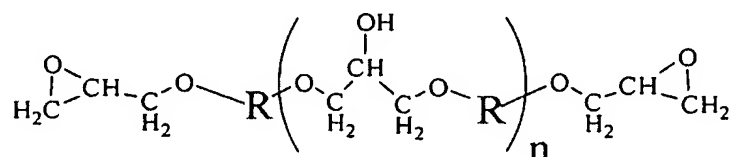
In accordance with the present invention, there is also provided a high purity epoxy resin composition and its hardened product used for sealing electronic parts that contain a high purity epoxy compound obtained by the above-described manufacturing method and a curing agent for the epoxy resin as essential components.

#### Description of the Preferred Embodiments

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An epoxy resin according to the present invention is a high purity epoxy compound with total chlorine content of 500 ppm or lower, which contains a bifunctional epoxy compound represented by the following general formula (I):

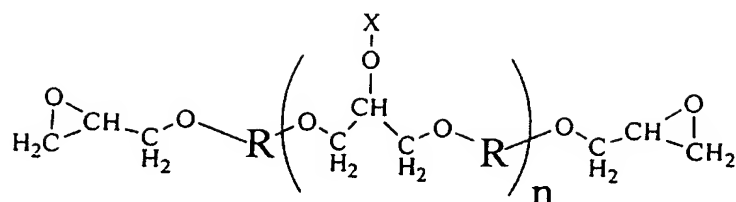
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(wherein,  $R$  represents a dihydric phenol compound residue and/or a dihydric alcohol compound residue; and  $n$  represents a numerical value with the average greater than 0 and not greater than 10), and a trifunctional epoxy compound represented by the following general formula (II):

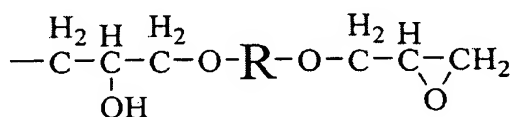




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[wherein, R represents a dihydric phenol compound residue and/or a dihydric alcohol compound residue; n represents a numerical value with the average greater than 0 and not greater than 10; and X is a hydrogen atom or a group represented by the following general formula (III):

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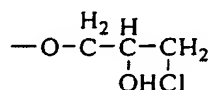
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(wherein, R has the above-mentioned meaning)]. Here, the term "total chlorine content" refers to the amount of chlorine as measured by the method specified in JIS K-7246, and usually all forms of chlorine-containing groups generated in an epoxy resin using epichlorohydrin are measured.

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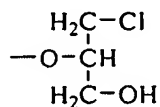
Specifically, 1,2-chlorohydrin containing group represented by the following formula (VI):

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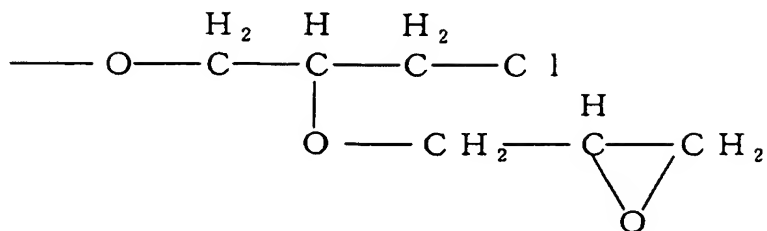


1,3-chlorohydrin containing group represented by the following formula (VII):

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and chloromethyl containing group represented by the following formula (VIII):



are known as chlorine-containing groups.

Among them, the chlorine-containing group which has 1,2-chlorohydrin containing group as main component is known as easily hydrolyzable chlorine, and can be decreased relatively easily. However, in order to assure high reliability, it is not sufficient to decrease the chlorine-containing group which has 1,2-chlorohydrin containing group as main component, but also 1,3-chlorohydrin containing group represented by the formula (VII) and chloromethyl containing group represented by the formula (VIII) need to be decreased. Especially when total chlorine content of an epoxy resin is 500 ppm or lower, the epoxy resin has remarkably excellent reliability. More preferably, total chlorine content is 350 ppm or lower.

The proportion of the component of the bifunctional epoxy compound of the general formula (I) used in the present invention with n equal to 0 is 70% or greater and less than 100%. If the proportion of the component with n equal to 0 is less than 70%, the epoxy resin exhibits undesirable increase in viscosity. Content of the component with n equal to 0 is preferably 75% ~ 99%, and more preferably 80% ~ 99%. Content of the component with n equal to 0 is analyzed using gel permeation chromatography with differential refractometer as a detector, and is numerically derived as area percentage of the obtained chromatogram.

The high purity epoxy compound of the present invention contains a multi-functional epoxy compound represented by the following general formula (II):



of stress reduction. More preferably the content is 1 ~ 6%, and still more preferably 2 ~ 5%. These compounds are measured by high performance liquid chromatography using an UV visible detector at the measuring wavelength of 285 nm, and the content is numerically derived from area percentage of the obtained chromatogram. These compounds are identified by high performance liquid chromatography using a mass spectrometer as a detector.

The high purity epoxy compound of the present invention is manufactured from bifunctional epoxy compound represented by the general formula (I), in which content of the component with  $n=0$  is not less than 70% and less than 100%, by adding 5 ~ 100 g of potassium hydroxide per 1 kg of the bifunctional epoxy compound, and causing the reaction to take place at temperature of 95 ~ 150°C and at concentration of aqueous potassium hydroxide solution in the system of not less than 80%.

Suitable examples of the bifunctional epoxy compounds represented by the general formula (I) includes conventionally known epoxy compound, such as: bisphenol type epoxy resins as reaction products of bisphenols such as bisphenol A, bisphenol F, bisphenol C, bisphenol K, bisphenol Z, bisphenol S, tetramethyl bisphenol A, tetramethyl bisphenol F, tetramethyl bisphenol S, tetramethyl bisphenol Z, etc., with epihalohydrin; biphenol type epoxy resins as reaction products of biphenols such as biphenol, tetramethyl biphenol, etc., with epihalohydrin; dihydroxy diphenyl sulfide type epoxy resins as reaction products of dihydroxy diphenyl sulfides such as dihydroxy diphenyl sulfide, 4,4-thiobis (3-methyl-6-tert-butylphenol), etc., with epihalohydrin; dihydroxy benzene type epoxy resins as reaction products of dihydroxy benzenes such as catechol, resorcin, methyl resorcin, hydroquinone, monomethyl hydroquinone, dimethyl hydroquinone, trimethyl hydroquinone, mono-tert-butyl hydroquinone, di-tert-butyl hydroquinone, etc., with

epihalohydrin; dihydroxy naphthalene type epoxy resins as reaction products of dihydroxy naphthalenes such as dihydroxy naphthalene, dihydroxy methyl naphthalene, dihydroxy methyl naphthalene, etc., with epihalohydrin.

5        These epoxy compounds are advantageously used in repeating unit of repetition number  $n$ , the average of which is preferably 10 or less (excluding 0), more preferably 5 or less, and still more preferably 3 or less. The average of the number  $n$  can be determined, for  
10       example from the number average molecular weight as measured by GPC or the like, or from the measurement of epoxy equivalent representing the terminal functional group.

15       Examples of suitable epoxy compounds also include epoxy resins as reaction products of phenols such as condensation products of phenols and/or naphthols and aldehydes, condensation products of phenols and/or naphthols and xylylene glycol, condensation products of phenols and/or naphthols and isopropenyl acetophenone,  
20       reaction products of phenols and/or naphthols and dicyclopentadiene, condensation products of phenols and/or naphthols and biphenyl type condensing agents, etc., with epihalohydrin.

25       Examples of the above-mentioned phenols include phenol, cresol, xylenol, butyl phenol, amyl phenol, nonyl phenol, butylmethyl phenol, trimethyl phenol, phenyl phenol, etc. Examples of the above-mentioned naphthols include 1-naphthol, 2-naphthol, etc.

30       Examples of aldehydes include formaldehyde, acetaldehyde, propyl aldehyde, butyl aldehyde, valer aldehyde, capron aldehyde, benzaldehyde, chloroaldehyde, bromoaldehyde, glyoxal, malon aldehyde, succinaldehyde, glutaraldehyde, adipinaldehyde, pimelinaldehyde, sebacinaldehyde, acrolein, crotonaldehyde,  
35       salicylaldehyde, phthalaldehyde, hydroxybenz aldehyde, etc.

      Examples of biphenyl type condensing agents include

bis(methylol) biphenyl, bis(methoxymethyl) biphenyl, bis(ethoxymethyl) biphenyl, bis(chloromethyl) biphenyl, etc.

Other specific examples of bifunctional epoxy  
5 compounds represented by the general formula (I) include epoxy resins as reaction products of ethylene oxide and/or propylene oxide adducts of bisphenols such as bisphenol A, bisphenol F, bisphenol C, bisphenol K, bisphenol Z, bisphenol S, tetramethyl bisphenol A,  
10 tetramethyl bisphenol F, tetramethyl bisphenol S, tetramethyl bisphenol Z, etc., with epihalohydrin; epoxy resins as reaction products of ethylene oxide and/or propylene oxide adducts of biphenols such as biphenol, tetramethylbiphenol, etc., with epihalohydrin; epoxy  
15 resins as reaction products of ethylene oxide and/or propylene oxide adducts of dihydroxy diphenyl sulfides such as dihydroxy diphenyl sulfide, 4,4-thiobis(3-methyl-6-tert-butylphenol), etc., with epihalohydrin; dihydroxybenzene type epoxy resins as reaction products  
20 of ethylene oxide and/or propylene oxide adducts of dihydroxybenzenes such as catechol, resorcin, methyl resorcin, hydroquinone, monomethyl hydroquinone, dimethyl hydroquinone, trimethyl hydroquinone, mono-tert-butyl hydroquinone, di-tert-butyl hydroquinone, etc., with  
25 epihalohydrin; and epoxy resins as reaction products of alcohols such as 1,4-butanediol, 1,6-hexanediol, 1,4-dihexanedimethanol, etc., with epihalohydrin.

The reaction according to the manufacturing method of the present invention requires addition of 5 ~ 100 g  
30 of alkali metal hydroxide per 1 kg of the epoxy compound. Suitable alkali metal hydroxide include sodium hydroxide, potassium hydroxide, etc. Preferably, potassium hydroxide is used, and may be used in the form of solid or as aqueous solution. Amount of the added potassium  
35 hydroxide may vary depending on the total chlorine content of the epoxy compound to be reacted, within the

range of 5 ~ 100 g per 1 kg of the epoxy compound.

If this amount is less than 5 g, sufficient effect on decrease of the total chlorine content cannot be obtained. If the added amount is more than 100 g per 1 kg of the epoxy compound, significant effect on decrease of the total chlorine content cannot be obtained, and increase of the consumption of potassium hydroxide entails undesirable increase of production cost. The added amount per 1 kg of the epoxy compound is preferably 5 ~ 80 g, and more preferably 10 ~ 50 g. The repetition number n of the repeating units in the multi-functional epoxy compounds represented by the general formula (II) is preferably not greater than 10 in average (excluding 0), more preferably not greater than 5, and still more preferably not greater than 3.

Reaction temperature of the above-mentioned reaction is in the range of 95 ~ 150°C. If the reaction temperature is lower than 95°C, effect on the decrease of total chlorine content and production of the multi-functional epoxy compound represented by the general formula (II) are not satisfactory. If the reaction temperature is higher than 150°C, undesirable remarkable decrease of the epoxy group and gel formation may occur. More preferably, the reaction temperature is 120 ~ 140°C. The reaction may be performed under reduced pressure, under ordinary pressure, or under high pressure, but is preferably performed under ordinary pressure in view of inexpensive production equipment. Reaction time (duration) is preferably 10 minutes ~ 10 hours, but is typically 30 minutes ~ 5 hours.

It is also necessary for the reaction to be performed under the condition that the concentration of aqueous solution of the alkali metal hydroxide in the reaction system is 80% or higher. If water content in the reaction system is too high, water is likely to react

with the epoxy group, leading to undesirable increase in epoxy equivalent. Thus, when water is present in the reaction system, it is necessary to perform dehydration treatment in advance such that, when potassium hydroxide  
5 is added, concentration of the aqueous solution of 80% or higher is obtained. Examples of this dehydration treatment include dehydration by heating under ordinary pressure or under reduced pressure, dehydration using dehydrating agent such as sodium sulfate anhydride,  
10 molecular sieve, etc.

The reaction may be performed in the presence of an organic solvent. Examples of suitable organic solvents include ketone based solvents such as methyl ethyl ketone, methyl isobutyl ketone, etc., hydrocarbon based  
15 solvents such as toluene, xylene, etc., alcohol based solvents such as methanol, ethanol, etc., cellosolve based solvents such as methyl cellosolve, ethyl cellosolve, etc., ethers such as dioxane, diethoxy ethane, etc., amide based solvents such as dimethyl  
20 formamide, etc., polar aprotic solvents such as dimethylsulfoxide, etc. Especially preferable solvents are methyl isobutyl ketone, and toluene. Phase transfer catalysts such as quaternary ammonium salt, quaternary phosphonium salt, etc., may also be used.

25 Potassium hydroxide used in the reaction is preferably in the form of solid potassium hydroxide of 90% or higher in purity. By using solid potassium hydroxide, introduction of unnecessary moisture into the system can be minimized. Especially, purity of 95% or  
30 higher is more preferable.

The reaction of the epoxy compound with potassium hydroxide preferably takes place in the presence of a tertiary alcohol. When a tertiary alcohol is present, potassium hydroxide can be effectively dispersed even if  
35 water content in the system is low. Therefore, this is desirable, since reaction proceeds smoothly, and reaction time, as well as consumption of potassium hydroxide, can



be reduced. Further, unlike primary and secondary alcohol, tertiary alcohol is difficult to react with epoxy group, and therefore, decrease of epoxy group or other undesirable reaction is unlikely to occur.

5 Examples of tertiary alcohols include tert-butyl alcohol.

The high purity epoxy resin composition of the present invention is an epoxy resin composition for sealing electronic parts, which comprises, as essential components, a high purity epoxy compound having specified  
10 branching structure of the present invention and a curing agent for the epoxy resin. The epoxy resin composition of the present invention may be used in conjunction with conventionally known epoxy resins such as bisphenol type epoxy resins, bromo-bisphenol type epoxy resins, novolac  
15 type epoxy resins, aliphatic epoxy resins, alicyclic epoxy resins, or the like.

The high purity epoxy resin of the present invention comprises a curing agent for the epoxy resin as an essential component, and any conventionally known curing  
20 agent for epoxy resins may be used. Specific examples include bisphenols such as bisphenol A, bisphenol F, bisphenol C, bisphenol K, bisphenol Z, bisphenol S, tetramethyl bisphenol A, tetramethyl bisphenol F, tetramethyl bisphenol S, tetramethyl bisphenol Z,  
25 dihydroxy diphenyl sulfide, 4,4-thiobis (3-methyl-6-tert-butylphenol), etc., dihydroxy benzenes such as catechol, resorcin, methyl resorcin, hydroquinone, monomethyl hydroquinone, dimethyl hydroquinone, trimethyl hydroquinone, mono-tert-butyl hydroquinone, di-tert-butyl  
30 hydroquinone, etc., dihydroxy naphthalenes such as dihydroxy naphthalene, dihydroxy methyl naphthalene, dihydroxy methyl naphthalene, trihydroxy methyl naphthalene, etc., and phenol compounds such as condensation products of phenols and/or naphthols and  
35 aldehydes, condensation products of phenols and/or naphthols and xylylene glycol, condensation products of phenols and/or naphthols and isopropenyl acetophenone,

reaction products of phenols and/or naphthols and dicyclopentadiene, condensation products of phenols and/or naphthols and biphenyl type condensing agents, etc.

5           The above-mentioned phenols include phenol, cresol, xylenol, butyl phenol, amyl phenol, nonyl phenol, butylmethyl phenol, trimethyl phenol, phenyl phenol, etc., and the above-mentioned naphthols include 1-naphthol, 2-naphthol, etc.

10           Examples of aldehydes include formaldehyde, acetaldehyde, propyl aldehyde, butyl aldehyde, valer aldehyde, capron aldehyde, benzaldehyde, chloroaldehyde, bromoaldehyde, glyoxal, malon aldehyde, succinaldehyde, glutaraldehyde, adipinaldehyde, pimelinaldehyde,  
15           sebacinaldehyde, acrolein, crotonaldehyde, salicylaldehyde, phthalaldehyde, hydroxybenz aldehyde, etc.

          Examples of biphenyl type condensing agents include bis(methylol) biphenyl, bis(methoxymethyl) biphenyl,  
20           bis(ethoxymethyl) biphenyl, bis(chloromethyl) biphenyl, etc.

          Other commonly known curing agents include acid anhydrides such as methyl tetrahydro phthalic anhydride, hexahydro phthalic anhydride, pyromellitic dianhydride,  
25           phthalic anhydride, trimellitic anhydride, etc., and amine based compounds such as diethylene triamine, triethylene tetramine, metaxylene diamine, isophorone diamine, diaminodiphenyl methane, diaminodiphenyl sulfone, diaminodiphenyl ether, dicyan diamide, and  
30           polyamidamine as condensation products of dimer acids and polyamines.

          Examples of curing agents which act as curing agents by inducing polymerization of epoxy groups include phosphine compounds such as triphenyl phosphine,  
35           phosphonium salts such as tetraphenyl phopsphonium bromide, imidazoles such as 2-methyl imidazole, 2-phenyl imidazole, 2-ethyl-4-methyl imidazole, 2-undecyl

imidazole, 1-cyanoethyl-2-methyl imidazole, etc., and imidazole salts thereof with trimellitic acid, isocyanuric acid, and boron, etc., amines such as benzyl dimethyl amine, 2,4,6-tris(dimethylaminomethyl) phenol, etc., quaternary ammonium salts such as trimethyl ammonium chloride, etc., diazabicyclo compounds and salts thereof with phenols, phenol novolac resins, etc., complex of boron trifluoride with amines, ether compounds, etc., aromatic phosphonium or iodonium salts. These curing agents may be used alone or in combination of two or more of them.

Blending ratio of the curing agent for epoxy resin used in the epoxy resin composition of the present invention is 0.5 ~ 1.5 equivalent, preferably 0.8 ~ 1.2 equivalent, of the functional group of the curing agent per 1 equivalent of the epoxy group. Blending ratio of the curing agent that hardens the resin by inducing polymerization of the epoxy resin, is 0.1 ~ 10 parts by weight, preferably 0.2 ~ 5 parts by weight, relative to 100 parts by weight of the epoxy resin.

A curing accelerator may be used as required in the epoxy resin composition of the present invention. Examples of suitable curing accelerators include phosphines, imidazoles, tertiary amines, boron trifluoride, etc. These curing accelerators may be used alone or in combination of two or more of them. Blending ratio of the curing accelerator is 0.1 ~ 10 parts by weight, more preferably 0.2 ~ 5 parts by weight, per 100 parts by weight of total epoxy resins used in the epoxy resin composition.

Inorganic filler may be used as required in the epoxy resin composition. Examples of useful inorganic filler include fused silica, crystalline silica, glass powder, alumina, calcium carbonate, etc. These inorganic filler may be used alone or in combination of two or more

of them. Blending ratio is 30 ~ 98 % by weight, preferably 50 ~ 95 % by weight, relative to total weight of the epoxy resin composition.

5 Flame retardant, coupling agent, fiber reinforcing agent, pigment, and plasticizer may be blended as required to the epoxy resin composition of the present invention.

As the bifunctional epoxy compound used in the present invention, an epoxy compound represented by the  
10 general formula (IV) and/or the general formula (V) is preferable. Examples of the epoxy compound represented by the general formula (IV) include bisphenol type epoxy resin as reaction products of bisphenols such as  
15 bisphenol A, bisphenol F, bisphenol C, bisphenol K, bisphenol Z, bisphenol S, tetramethyl bisphenol A, tetramethyl bisphenol F, tetramethyl bisphenol S, tetramethyl bisphenol Z, etc., with epihalohydrin;

biphenol type epoxy resins as reaction products of biphenols such as biphenol, tetramethylbiphenol, etc.,  
20 with epihalohydrin; and dihydroxy diphenyl sulfide type epoxy resins as reaction products of dihydroxy diphenyl sulfides such as dihydroxy diphenyl sulfide, 4,4-thiobis (3-methyl-6-tert-butylphenol), etc., with epihalohydrin.

Examples of epoxy resins represented by the general  
25 formula (V) include dihydroxybenzene type epoxy resins as reaction products of dihydroxybenzenes such as catechol, resorcin, methyl resorcin, hydroquinone, monomethyl hydroquinone, dimethyl hydroquinone, trimethyl hydroquinone, mono-tert-butyl hydroquinone, di-tert-butyl  
30 hydroquinone, etc., with epihalohydrin.

#### Examples

Now, the present invention will be further described in detail below with reference to Examples and  
35 Comparative examples. It is to be understood, however, that the present invention is not limited to the

following Examples. The term "parts" as used herein refers to "parts by weight", unless otherwise specified. Epoxy equivalent, total chlorine content, component with  $n = 0$  as measured by GPC, and multi-functional epoxy compound having specified branching structure of the present invention as measured by HPLC, were measured using the methods as described in the following.

Epoxy equivalent

Sample was dissolved in dioxane, 0.1 N HCl dioxane solution was added and reaction took place at room temperature for 30 minutes. Titration with 0.1 N sodium hydroxide was conducted using cresol red as indicator. Difference of the required amount of titration between the test sample and blank test was determined and the amount of sample was divided by the difference to obtain epoxy equivalent (g/eq).

Total chlorine content

Measured value obtained in accordance with JIS K-7246 was taken as total chlorine content (ppm).

(Component with  $n = 0$  as measured by GPC)

GPC Analyzing apparatus HLC-8020 (manufactured by TOSOH Co.) was used for analysis with a differential refractometer as a detector. GPC column SYSTEM consisting of two G2000H<sub>XL</sub> and one G1000 H<sub>XL</sub> was used to separate the component with  $n = 0$ . Content of the component with  $n = 0$  was calculated from the obtained GPC chromatograph by dividing the peak area corresponding to the component with  $n = 0$  by the peak area of total components expressed as area percentage (%).

Multi-functional epoxy compound having specified branching structure of the present invention as measured by HPLC

HPLC Analyzer Series 1100 (manufactured by Agilent Technologies Co.) was used for analysis with an UV visible detector at measuring wavelength of 285 nm. The

HPLC column used was Cadenza CD-C<sub>18</sub> manufactured by Imtakt Co. (Column size, length 100 mm × inner diameter 4.6 mm). The multi-functional epoxy compound having specified branching structure of the present invention was separated using this column. Content of the multi-functional epoxy compound having specified branching structure of the present invention was calculated from the obtained HPLC chromatograph by dividing the peak area corresponding to the multi-functional epoxy compound having specified branching structure by peak area of total components expressed as area percentage (%).

Examples 1 ~ 2 and Comparative examples 1 ~ 2

Example 1

In a 1 L separable flask provided with a stirrer, a thermometer, and a condenser, 150 parts of diglycidyl ether of 1,4-di-tert-butyl-2,5-dihydroxy-benzene with epoxy equivalent of 177 g/eq, total chlorine content of 1200 ppm, having the component with n = 0 of 89% as measured by GPC, and not containing the multi-functional epoxy compound having the specified branching structure of the present invention as measured by HPLC, and 470 parts of toluene, were introduced and were heated to a temperature of 80°C to dissolve the resin. At the same temperature, 6.2 parts of solid potassium hydroxide of 97% in concentration was added, and was heated under agitation to a temperature of 115°C, and reaction was conducted for 1 hour at the same temperature.

After completion of the reaction, the reaction product was cooled to 80°C. After 50 parts of water was added to it to dissolve salts, it was allowed to rest to separate and remove the bottom aqueous phase and gel by-product. After neutralization with phosphoric acid solution, the resin solution was washed with water until the drained water became neutral, and was filtered.

Toluene was removed under the condition of 1.33 KPa

and 150°C to obtain the intended resin (epoxy resin A).

Conditions of reaction for this Example are shown in Table 1, and properties, yield, etc., of the obtained resin are shown in Table 2.

5        Example 2

Same procedure as in Example 1 was followed, except that 9.3 parts of solid potassium hydroxide of 97% in concentration and 0.7 part of water were added and the reaction was conducted at 100°C for 3 hours, to obtain the intended resin (epoxy resin B).

Conditions of reaction for this Example are shown in Table 1, and properties, yield, etc., of the obtained resin are shown in Table 2.

15        Comparative example 1

Same procedure as in Example 1 was followed, except that, in place of solid potassium hydroxide of 97% in concentration, 6.2 parts of sodium hydroxide of 97% in concentration was added and the reaction was conducted at 90°C for 3 hours, to obtain the intended resin (epoxy resin C).

Conditions of reaction for this Comparative example are shown in Table 1, and properties, yield, etc., of the obtained resin are shown in Table 2.

25        Comparative example 2

In a 1 L separable flask provided with a stirrer, a thermometer, and a condenser, 150 parts of diglycidyl ether of 1,4-di-tert-butyl-2,5-dihydroxy-benzene with epoxy equivalent of 176 g/eq, total chlorine content of 1200ppm, having the component with  $n = 0$  of 89% as measured by GPC, and not containing the multi-functional epoxy compound having the specified branching structure of the present invention as measured by HPLC, and 400 parts of methanol, were introduced and were heated to a temperature of 50°C and stirred at this temperature for 1 hour. While being stirred, the resin was not completely dissolved, and remained in slurry state. Then, the resin was cooled to 30°C, and the precipitated resin was

separated by filtration. Methanol was removed from the separated resin under the conditions of 1.33 KPa and 150°C to obtain the intended resin (epoxy resin D).

5 Properties, yield, etc., of the resin obtained in this comparative example are shown in Table 2.

Table 1

Manufacturing conditions	Unit	Example 1	Example 2	Comparative example 1
Type of alkali metal hydroxide		Potassium hydroxide	Potassium hydroxide	Sodium hydroxide
Form of alkali metal hydroxide		Solid	Solid	Solid
Concentration of alkali metal hydroxide	%	97	97	97
Added amount of alkali metal hydroxide per 1 kg of epoxy resin	g	40	60	40
Reaction temperature	°C	115	100	85
Concentration of alkali metal hydroxide during reaction	%	97	90	97



Table 2

Properties, yield, etc.	Unit	Example 1	Example 2	Comparative example 1	Comparative example 2
Name of resin		Epoxy resin A	Epoxy resin B	Epoxy resin C	Epoxy resin D
Epoxy equivalent	g/eq	183	181	180	<u>173</u>
Total chlorine content	ppm	240	460	610	<u>310</u>
Multi-functional epoxy compound of the invention as measured by HPLC	%	3.8	2.5	1.2	0.0
Content of n=0 as measured by GPC	%	82	84	82	93
Obtained amount	g	139	145	122	128
Yield	%	93	97	81	85

Example 3 ~ 4 and Comparative example 3 ~ 4

Example 3

5 In a 1 L separable flask provided with a stirrer, a thermometer, and a condenser, 150 parts of diglycidyl ether of 4,4'-dihydroxy-3,3',5,5'-tetramethyl biphenyl with epoxy equivalent of 186 g/eq, total chlorine content of 1100 ppm, having the component with n = 0 of 90% as measured by GPC, and not containing the multi-functional epoxy compound having the specified branching structure of the present invention as measured by HPLC, and 470 parts of methyl isobutyl ketone, were introduced and were heated to a temperature of 80°C to dissolve the resin.

15 At the same temperature, 8.5 parts of solid potassium hydroxide of 95% in concentration was added, and was heated under agitation to a temperature of 100°C, and reaction was conducted for 1 hour at this temperature. After completion of the reaction, the reaction product was cooled to 80°C. After 50 parts of

water was added to it to dissolve salts, it was allowed to rest to separate and remove the bottom aqueous phase and gel by-product. After neutralization with phosphoric acid solution, the resin solution was washed with water until the drained water became neutral, and was filtered. Methyl isobutyl ketone was removed under the condition of 1.33 KPa and 150°C to obtain the intended resin (epoxy resin E).

Conditions of reaction for this Example are shown in Table 3, and properties, yield, etc., of the obtained resin are shown in Table 4.

#### Example 4

Same procedure as in Example 3 was followed, except that 6.2 parts of solid potassium hydroxide of 95% in concentration was added and the reaction was conducted at 115°C, to obtain the intended resin (epoxy resin F).

Conditions of reaction for this Example are shown in Table 3, and properties, yield, etc., of the obtained resin are shown in Table 4.

#### Comparative example 3

Same procedure as in Example 3 was followed, except that, in place of solid potassium hydroxide of 95% in concentration, 12.7 parts of sodium hydroxide of 49% in concentration was added and the reaction was conducted at 85°C for 6 hours, to obtain the resin (epoxy resin G). Conditions of reaction for this Comparative example are shown in Table 3, and properties, yield, etc., of the obtained resin are shown in Table 4.

#### Comparative example 4

Same procedure as in Example 3 was followed, except that 0.3 part of solid potassium hydroxide of 95% in concentration was added and the reaction was conducted for 3 hours, to obtain the resin (epoxy resin H). Conditions of reaction for this Comparative example are shown in Table 3, and properties, yield, etc., of the obtained resin are shown in Table 4.

Table 3

Manufacturing conditions	Unit	Example 3	Example 4	Comparative example 3	Comparative example 4
Type of alkali metal hydroxide		Potassium hydroxide	Potassium hydroxide	Sodium hydroxide	Potassium hydroxide
Form of alkali metal hydroxide		Solid	Solid	Liquid	Solid
Concentration of alkali metal hydroxide	%	95	95	49	95
Added amount of alkali metal hydroxide per 1 kg of epoxy resin	g	54	40	40	2
Reaction temperature	°C	100	115	85	115
Concentration of alkali metal hydroxide during reaction	%	95	95	49	95

Table 4

Properties, yield, etc.	Unit	Example 3	Example 4	Comparative example 3	Comparative example 4
Name of resin		Epoxy resin E	Epoxy resin F	Epoxy resin G	Epoxy resin H
Epoxy equivalent	g/eq	193	190	190	188
Total chlorine content	ppm	120	320	780	880
Multi-functional epoxy compound of the invention as measured by HPLC	%	3.6	3.2	1.3	0.4
Content of n=0 as measured by GPC	%	83	84	82	78
Obtained amount	g	142	145	114	146
Yield	%	95	97	76	97

5

Example 5 ~ 6 and Comparative example 5 ~ 6

Example 5

In a 1 L separable flask provided with a stirrer, a thermometer, and a condenser, 150 parts of diglycidyl

ether of bisphenol A with epoxy equivalent of 177 g/eq, total chlorine content of 900 ppm, content of the component with  $n = 0$  of 90% as measured by GPC, and not containing the multi-functional epoxy compound having the specified branching structure of the present invention as measured by HPLC, and 450 parts of toluene and 20 parts of tert-butyl alcohol, were introduced and were heated to a temperature of 80°C to dissolve the resin. At the same temperature, 8.4 parts of solid potassium hydroxide of 95% in concentration was added, and was heated under agitation to a temperature of 115°C, and reaction was conducted for 1 hour at this temperature.

After completion of the reaction, the reaction product was cooled to 80°C. After 50 parts of water was added to it to dissolve salts, it was allowed to rest to separate and remove the bottom aqueous phase and gel by-product. After neutralization with phosphoric acid solution, the resin solution was washed with water until the drained water became neutral, and was filtered.

Toluene was removed under the condition of 1.33 KPa and 150°C to obtain the intended resin (epoxy resin K). Conditions of reaction for this Example are shown in Table 5, and properties, yield, etc., of the obtained resin are shown in Table 6.

#### Example 6

Same procedure as in Example 5 was followed, except that 6.3 parts of solid potassium hydroxide of 95% in concentration was added and the reaction was conducted at 95°C for 3 hours, to obtain the intended resin (epoxy resin L). Conditions of reaction for this Example are shown in Table 5, and properties, yield, etc., of the obtained resin are shown in Table 6.

#### Comparative example 5

In a 1 L separable flask provided with a stirrer, a thermometer, a condenser, and an oil-water separator, 150 parts of diglycidyl ether of bisphenol A with epoxy equivalent of 178 g/eq, total chlorine content of 900

ppm, content of the component with  $n = 0$  of 90% as measured by GPC, and not containing the multi-functional epoxy compound having the specified branching structure of the present invention as measured by HPLC, and 470  
5 parts of toluene, were introduced and were heated to a temperature of 80°C to dissolve the resin. At the same temperature, 12 parts of sodium hydroxide of 48% in concentration was added, and was heated under agitation to a temperature of 90°C, and reaction was conducted for  
10 1 hour at this temperature.

During heating and reaction, water was boiled in azeotrope with toluene, and was passed through the oil-water separator to remove water out of the system. After completion of reaction, the reaction product was cooled  
15 to 80°C. After 50 parts of water was added to it to dissolve salts, it was allowed to rest to separate and remove the bottom aqueous phase and gel by-product. After neutralization with phosphoric acid solution, the resin solution was washed with water until the drained  
20 water became neutral, and was filtered. Toluene was removed under the condition of 1.33 KPa and 150°C to obtain the intended resin (epoxy resin M). Conditions of reaction for this Example are shown in Table 5, and properties, yield, etc., of the obtained resin are shown  
25 in Table 6.

Table 5

Manufacturing conditions	Unit	Example 5	Example 6	Comparative example 5
Type of alkali metal hydroxide		Potassium hydroxide	Potassium hydroxide	Sodium hydroxide
Form of alkali metal hydroxide		Solid	Solid	Liquid
Concentration of alkali metal hydroxide	%	95	95	48
Added amount of alkali metal hydroxide per 1 kg of epoxy resin	g	53	40	40
Reaction temperature	°C	100	115	90
Concentration of alkali metal hydroxide during reaction	%	95	95	48

Table 6

Properties, yield, etc.	Unit	Example 5	Example 6	Comparative example 5
Name of resin		Epoxy resin K	Epoxy resin L	Epoxy resin M
Epoxy equivalent	g/eq	184	180	179
Total chlorine content	Ppm	110	280	600
Multi-functional epoxy compound of the invention as measured by HPLC	%	4.2	3.8	1.9
Content of n=0 as measured by GPC	%	88	87	82
Obtained amount	g	132	140	118
Yield	%	88	93	77

5                    Comparative manufacture example 1

10                   In a 1 L separable flask provided with a stirrer, a thermometer, and a condenser, 100 parts of epoxy resin E, 2.2 parts of 1,4-di-tert-butyl-2,5-dihydroxy-benzene, and 5 parts of xylene were mixed and heated to a temperature of 130°C. At the same temperature, 0.5 part of triphenyl phosphine was added, and reaction was conducted at 160°C for 5 hours. After completion of the reaction, xylene was removed by evaporation to obtain epoxy resin (epoxy resin N) with eoxy equivalent of 183 g/eq, total chlorine

content of 290 ppm, content of the component n=0 of 83% as measured by GPC, and not containing multi-functional epoxy compound having the specified branching structure of the present invention as measured by HPLC.

5           Example 7 ~ 8 and Comparative example 6 ~ 7

          Epoxy resin compositions were blended using the epoxy resins A ~ B and epoxy resins C ~ D as shown in Table 2, and epoxy resin N prepared in the Comparative manufacture example 1 in order to clearly show the effect  
10       of the present invention, and phenol aralkyl resin as a curing agent for epoxy resin, triphenyl phosphine as a curing accelerator, Carnauba Wax as releasing agent, epoxy silane as a silane coupling agent, and using  
15       spherical silica powder as inorganic filler in an amount of 87% by weight relative to total weight of the epoxy resin, curing agent for the epoxy resin and silica powder.

          Then, each blend was kneaded at a temperature of 100 ~ 120°C, and after cooling, was pulverized to obtain each  
20       material. Each blend is shown in Table 7. Each material was molded using a low pressure transfer molding machine at under conditions of die temperature of 170°C and pressure of 64 kg/cm<sup>2</sup>, for molding time of 120 seconds, to obtain each test sample. These samples were subjected  
25       to post-cure processing at 180°C for 6 hours. Various measurements were performed on the obtained samples, including flexural strength and elastic modulus at room temperature, flexural strength and elastic modulus when heated to a temperature of 250°C, glass transition  
30       temperature, coefficient of water absorption at 85°C and relative humidity of 85% for 72 hours, and electrical conductivity of pure water and total extracted chlorine ion content when the sample was frozen and pulverized to 100 ~ 150 mesh, and 10 g of the pulverized sample and 40  
35       g of pure water was extracted in a Teflon pressure vessel at 180°C for 30 hours, and the results of the measurement

are shown in Table 8.



Table 7

Blending ratio	Unit	Example 7	Example 8	Comparative example 6	Comparative example 7	Comparative manufacture example 1
Type of epoxy resin		Epoxy resin A	Epoxy resin B	Epoxy resin C	Epoxy resin D	Epoxy resin N
Epoxy resin	parts	100	100	100	100	100
Curing agent for epoxy resin *1	parts	95.5	96.6	94.1	101	95.5
Inorganic filler *2	parts	1308	1316	1299	1345	1308
Curing accelerator *3	parts	2.3	2.3	2.3	2.3	2.3
Releasing agent	parts	1.9	1.9	1.9	1.9	1.9
Silane coupling agent *4	parts	9	9	9	9	9
Carbon black	parts	1	1	1	1	1

\*1 : Phenol aralkyl resin MEH-7800S, hydroxyl equivalent of 175 g/eq, manufactured by Meiwa Plastic Industries Co.

\*2 : manufactured by Denki Kagaku Kogyo Co. Spherical fused silica powder blended in the following ratio.

20 % by weight of FB-60 with average particle size of 25  $\mu$ m.

50 % by weight of FB-35 with average particle size of 10  $\mu$ m.

30 % by weight of SO-C3 with average particle size of 0.7  $\mu$ m.

\*3 : Triphenyl phosphine

\*4 : Eoxy silane KBM-403, manufactured by Shinetsu Silicone Co.

Table 8

Characteristic values	Unit	Example 7	Example 8	Comparative example 6	Comparative example 7	Comparative manufacture example 1
Type of epoxy resin		Epoxy resin A	Epoxy resin B	Epoxy resin C	Epoxy resin D	Epoxy resin N
Flexural strength at room temperature	kg/mm <sup>2</sup>	11.85	11.87	11.82	12.08	11.21
Flexural elastic modulus at room temperature	kg/mm <sup>2</sup>	1460	1480	1480	1560	1405
Flexural strength when heated	kg/mm <sup>2</sup>	0.88	0.90	0.82	0.91	0.72
Flexural elastic modulus when heated	kg/mm <sup>2</sup>	45.2	46.5	45.8	55.3	45.3
Glass transition temperature	°C	114	115	107	117	110
Water absorption ratio	%	0.175	0.178	0.182	0.186	0.188
Electrical conductivity	μS/cm	48	90	125	88	105
Chlorine ion	ppm	13	23	62	20	42

#### Industrial Applicability

The high purity epoxy resin of the present invention has excellent thermal resistance, low hygroscopicity, and excellent mechanical properties. In addition, since  
5 elution of ionic impurities is low, the epoxy resin of the invention can be advantageously used in an epoxy resin composition as sealing material in the field of electric and electronic devices. The manufacturing  
method for manufacturing the high purity epoxy resin  
10 according to the present invention is industrially useful in that it permits the high purity epoxy resin of the invention to be produced easily and at high yield.